

Digital Radiography Qualification of Tube Welding

Description: The Orion Project will be directing Lockheed Martin to perform orbital arc welding on commodities metallic tubing as part of the Multi Purpose Crew Vehicle assembly and integration process in the Operations and Checkout High bay at Kennedy Space Center. The current method of nondestructive evaluation is utilizing traditional film based x-rays. Due to the high number of welds that are necessary to join the commodities tubing (approx 470), a more efficient and expeditious method of nondestructive evaluation is desired. Digital and computed radiography will be compared to traditional film x-rays as part of a broader NASA Nondestructive Working Group (NNWG) capability study.

The spacecraft tubing material consists of 316L stainless steel, Monel 400, and Titanium Grade 2 (Ti-3Al-2.5V) in various outer diameters to closely replicate what Lockheed Martin has selected for the crew module. Material wall thicknesses vary from 0.035" to 0.049". This project utilizes 90 tube weld samples for the comparison. Each size and material listed below contained 10 good tube welds, 10 tube welds containing porosity and 10 tube welds containing lack of fusion.

Stainless Steel - 0.25 inch diameter - 0.035 thru wall

Stainless Steel - 0.50 inch diameter - 0.049 thru wall

Monel - 0.50 inch diameter - 0.049 thru wall



Figure 1: Orion Tube Weld Samples

Three methods of inspection media were initially used for this comparison. They include the standard film technique, Computed Radiography (CR) and Digital Radiography (DR). For all methods, the same x-ray tube was utilized for consistency. Digital Radiography was eliminated from trial early on in favor of Computed Radiography. This project was performed to determine the relative capability between film and non-film Radiographic methods for welded tubing.

Two advantages of standard film radiography are radiographic sensitivity and film viewing mobility. Due to the CR system's limited resolution of 50 microns, film resolution was more sensitive when viewing linear indications due to the increased resolution of film. During the comparison of the aforementioned techniques there were, however, instances where scanning the film increased the radiographic latitude. That, in conjunction with using inherent software filters and contrast enhancements, brought out certain features and indications even though the film was digitally scanned in at 50 microns.

Both standard film and CR techniques easily met 2-1T sensitivity. The most discrepancies between the two methods appeared in the 0.25" SS samples in which the CR appeared to outperform the film. Porosity was detected using both methods with measurement being

consistent between the two. This includes pores that were well below the reject criteria (isolated pore = 0.012 inches) per Lockheed Martin MAP-801033 criteria.

Lack of Fusion (LOF) detection appeared to be slightly better with CR, but only with digital filtering and enhancement tools that are not available with film radiography. Lengths of defects varied between tube specimens due to sensitivity variations with the resolution of each technique, but also due to tube angle. Another factor was tube weld rotation during inspection. The 0 degree slightly altered from method to method. One disadvantage of CR is the presence of darker lines in the same direction as the weld interface and may cause a false positive. Difficulties also arose when reading the film near the darker heat affected zones where sharp transitions that were possible LOF indications occurred.

The results of this study showed that both radiographic techniques are feasible for tube weld inspections. The demonstration of the various CR systems clearly showed that another significant step has been taken in this technology with regards to both radiographic CR panels, as well as their scanners. The screens show that although the resolution capability limit of the Kodak XL blue is approximately 30 microns and 7 lp/mm at best, it is over twice as efficient. In contrast, the GE IPU is much slower than its Kodak counterpart, but the resolution capability of the plate is significantly higher. The GE IPU is able to produce high contrast images in the 12 micron image pixel size with spatial resolution of well over 10lp/mm which brings it into the realm of high quality Class I film such as the Fuji 50 that was used in this particular study.

The high-resolution CR radiographs are very dependent on both the CR scanner hardware and the image viewing and processing software that is coupled with the scanner. The results show that while both the Carestream HPX-1 and GE CR25P were able to obtain 25 micron images, neither system was able to produce the high resolution images of the ScanX HR system coupled with the Digicon PixelRay software. The combination of the ScanX HR hardware with the PixelRay software produced the most comparable results to Class I film to date. The resolution of the system was significantly higher than the required minimum requirement for thin walled tubes. Its resolution capability at 12 microns was able to resolve at least 10 lp/mm, which is comparable to the Fuji 50 film and is paramount for highly accurate LOF detection capability.